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Renewable energy resource potential in Pakistan

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ABSTRACT

Pakistan energy situation is seriously troubling today due to lack of careful planning and implementation of its energy policies. To avoid the worse situation in the years ahead, the country will have to exploit its huge natural renewable resource. In this paper a review is being presented about renewable energy resource potential available in the country to be exploited for useful and consistent energy supplies. On average solar global insolation 5–7 kWh/m^2/day, wind speed 5–7.5 m/s, Biogas 14 million m^3/day, microhydel more than 600 MW (for small units) with persistency factor of more than 80% over a year exist in the country. Solar and wind maps are presented along with identification of hot spring sites as resource of geothermal energy. The research results presented in this paper are not only useful for government policy makers, executing agencies but also for private sector national and international agencies and stake holders who want to invest in Pakistan for renewable energy projects or business.

Contents

1. Introduction

Fig. 1 summarizes the primary energy supply picture for the country. Total energy supplies were 62.8 MTOE (Million Tons of Oil Equivalent) in fiscal year 2007–2008. With an annual production of 3984 million cubic feet per day (29 MTOE) gas accounts for 48.5% of energy supplies, followed by oil at 30%, hydel and nuclear at 13.7% and coal at 7.3% [1]. Pakistan currently meets only 20% of its oil demand from indigenous resources. In this energy supply scenario, the renewable energy total contribution is in the range of a fraction of a percentage depicting an ignored sector of power/energy generation in spite of the fact that many times natural renewable energy resource potential as compared to conventional energy resource exists in the country. Considering an example of solar potential, naturally gifted sunshine with available insolation density is sufficient to produce 60 MTOE of energy just with a cover of 25 km × 25 km area of land with 10% efficient solar energy converters. Ignoring such facts, Pakistan is striving for import of power from central Asia, Tajikistan, Kyrgyzstan, and gas from Turkmanistan, Iran and Qatar. No doubt priority should be given to such projects but exploitation of the domestic resource base is also very essential to build self-reliance and save foreign exchange for economic growth. In the following sections, the available resource potential is identified quantitatively. Engineers, researchers, energy planners and policy makers can make best use of this data for generation of renewable energy and its dissemination in the country.

2. Solar energy

Figs. 2 and 3 depict solar maps of Pakistan drawn through satellite imaginary technique. The satellite estimation of solar

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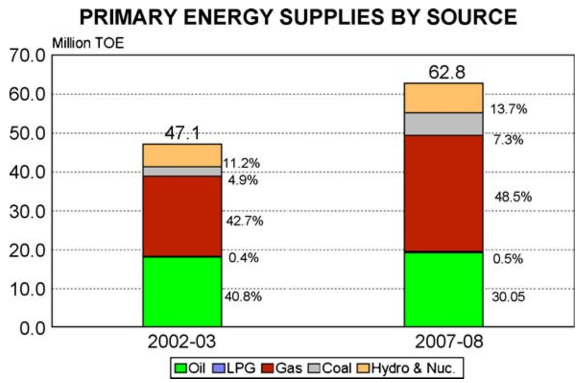


Fig. 1. Pakistan primary energy supplies for the year 2007–2008.

irradiance at the surface of earth has been presented by Dedieu et al. [2], Diabate et al. [3] and over Pakistan by Malik et al. [4], Shamshad [5], Ghaffar [6] respectively. Dedieu et al. computed solar irradiance "E_0" at the earth's surface using the following relationship:

$$E_0 = \frac{Ed^{-2}\cos(Q_s)T(Q_s)(1-A)}{(1-A_s)} \tag{1}$$

where "E" is the solar constant, "d" is the radius vector (the ratio of actual to mean sun–earth distant), Q_s the solar zenith angle, $T(Q_s)$ a clear sky transmission factor accounting for gaseous absorption and Rayleigh and Mie scattering, "A" is the planetary albedo viewed by the satellite and "A_s" is the surface albedo. Solar maps of

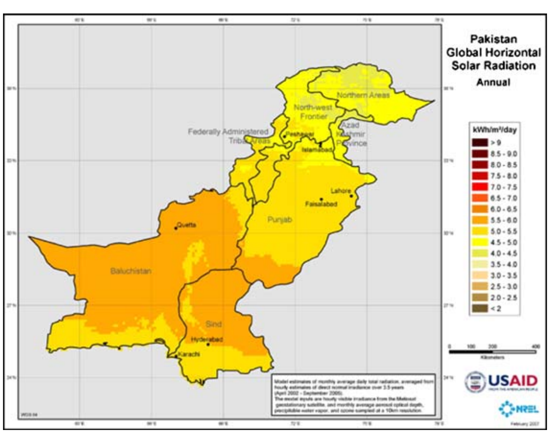


Fig. 2. Pakistan solar map (for global radiation).

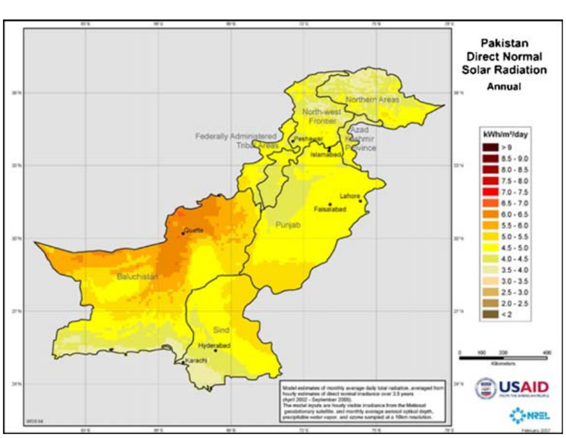


Fig. 3. Pakistan solar map (for direct normal radiation).

Pakistan for the months of May, 1986 and August/October, 1985 at 1100 h only were depicted by Malik et al. [4] using the same computer model. But the data presented so far about Pakistan is not very elaborate and comprehensive. The values of annual global horizontal insolation and annual irradiance data at flat plate at latitude have been shown in Figs. 2 and 3 respectively. In these figures, the computer model estimates of monthly average daily total radiation, averaged from hourly estimates of direct normal irradiance over 3.5 years (April 2002–September 2005) are presented. The model inputs are hourly visible irradiance from the Metiosat geostationary satellite and monthly average aerosol optical depth, precipitation water vapor and ozone sampled at a 10 km resolution.

These figures show that Pakistan has huge favourable solar resource potential for energy generation. The average daily insolation amounts to approximately 5–7 kWh/m^2/day. Especially the southwestern province of Balochistan and Northeastern part of Sind offers excellent conditions for harnessing solar energy. There the sun shines between 6 to 8 h daily or approximately more than 2300–2700 h per annum. The average daily insolation of 5–7 kWh/m^2/day means daily sun energy of 18–25 MJ/m^2/day is available as input natural resource of energy to be exploited for photovoltaic power generation or solar thermal applications. The useful conversion of input energy depends upon system/product efficiency. For photovoltaic (PV) power generation with 14% efficient PV panels installed over area of 10×10 km^2 and using the formula [7]:

$$C_0 = \eta \times I_0 \times A \times 0.5$$

where C_0 = possible PV array generation capacity (watts); η = efficiency of PV panel (%); I_0 = incident solar radiation (W/m^2); A = area coverage by PV panels (m^2); 0.5 = space factor.

PV generation capacity of 5.6 GW can be attained with average insolation of 0.8 kW/m^2. Based on annual sunshine hours of 2125 at the locality, the annual PV electric energy generation comes to be 8.33×10^3 GWh by using the formula [7]:

$$E_{pv} = C_0 \times 0.7 \times H$$

where H = annual sunshine hours (h); 0.7 = system performance ratio.

So covering 10×10 km^2 area of land in Pakistan with PV panels can produce energy equivalent to 30 MTOE whereas total energy demand of the country is presently estimated to be 62 MTOE. Similarly more than 70% efficient solar thermal appliances are available which can be employed for meeting thermal energy demands of the country especially during winter seasons. Despite favourable conditions, the use of solar energy for generating electricity or heating is still in its beginnings.

3. Wind energy

Wind map of Pakistan is shown in Fig. 4. Wind data taken through satellite is at 50 m height from ground showing existence of good potential in localized regions. Wind speed from 5 m/s to 7 m/s persists in coastal regions of Sind and Balochistan provinces and in a number of North-West Frontier valleys. According to a survey, Pakistan processes more than 20,000 MW of economically viable wind power potential.

For the assessment of wind power potential available in the country, most of survey was conducted by Pakistan Meteorological Department through financial assistance of Ministry of Science and Technology. The areas of interest were coastal regions, Northern Areas and Sind Province of Pakistan. Wind assessment systems were installed at various localities in these areas and wind data with one-minute average speed and direction was collected at 10 m and 30 m height and 50 m height values were computed from

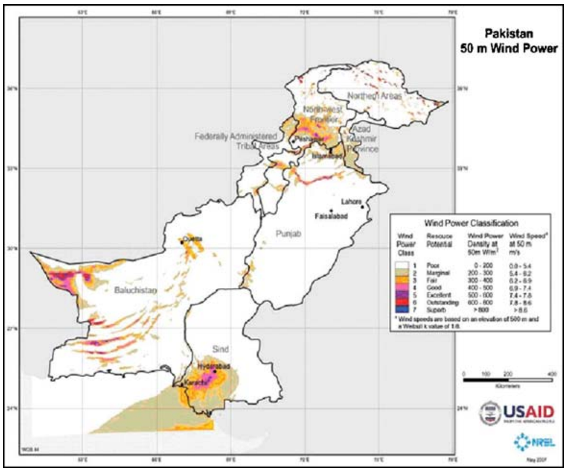


Fig. 4. Pakistan wind map.

mathematical models. Wind generated electric power densities were computed on hypothetical 600 kW wind turbine.

Forty-two stations for collecting wind data were installed in Northern Areas of Pakistan including districts of Swat, Dir, Chitral, Gilgit, Skardu, Haripur, Shangla, Buneer, Nowshera, Peshawar, Mohmand Agency, Khyber Agency and Azad Kashmir. Fig. 5 depicts such installation. Wind resource potential of Northern Areas of Pakistan is not attractive for wind power generation. In 2007, the annual power densities of Khungipayan (Dir/NWFP) and Shaheed Gali (AJK) remained 27.49 W/m^2 and 208.19 W/m^2 with highest wind speed of 2.61 m/s and 6.53 m/s respectively [8,9]. According to international wind classification, most of regions of Northern Areas are catagorized as a below marginal site for wind power generation. Whereas the survey of coastal areas of Pakistan has indicated that tremendous potential exists for harnessing wind energy especially in the wind corridor around Gharo in Sind. During three years (2004–2007) study period, wind data was collected at 20 sites along the Sind coast, Fig. 6. The wind speed at 50 m height has given annual average wind speeds of 8.5 m/s, 7.0 m/s, 7.0 m/s, 6.7 m/s and 6.6 m/s at Jamshoro, Katibandar, Nooriabad Thatta and Gharo respectively. The extrapolated data of wind speed at 50 m height was computed using Log law [10]

$$\mu = \frac{\mu_f}{k}\left[\frac{[\ln(Z-D)]}{Z_0}\right]$$

where μ_f = friction factor; k = Von Karman constant; Z_0 = roughness length; D = displacement height

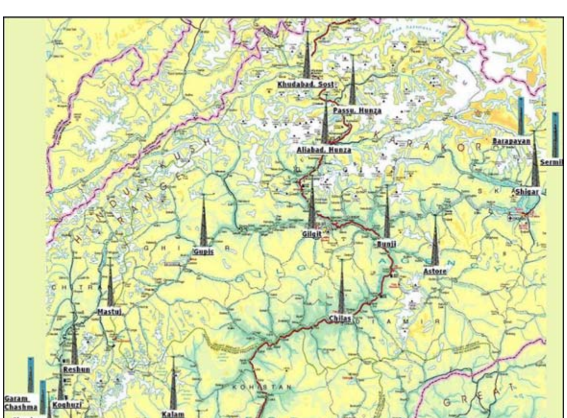


Fig. 5. Wind mapping sites in Northern areas of Pakistan.

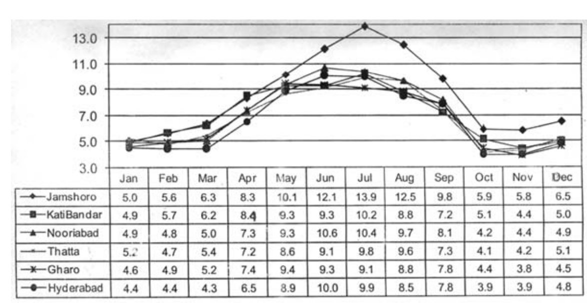
Fig. 6. Wind mapping sites in Sind coastal areas of Pakistan.

The wind speed at any height (Z) can be computed provided that the wind speed at height Z_R is known. Thus

$$\frac{\mu}{\mu_R} = \frac{\ln(Z/Z_0)}{\ln(Z_R/Z_0)}$$

where μ_R is the wind speed at reference height Z_R.

During six months' period from April through September, average wind speed at the above-mentioned sites is found to be more than 11.11 m/s, 8.87 m/s, 9.23 m/s, 8.6 m/s and 8.63 m/s respectively. The monthly average wind speed at 50 m in six windy stations of Sind is shown in Fig. 7. The annual wind power densities at Jamshoro, Nooriabad, Talhar, Katibandar, Thatta, Thana Bulkhan, Hyderabad and Gharo have been found to be 770 W/m^2, 454 W/m^2, 445 W/m^2, 374 W/m^2, 373 W/m^2, 371 W/m^2 and 359 W/m^2 respectively. According to international wind classification, this power density categorizes Jamshoro, Nooriabad, Talhar and Katibandar as excellent sites, and Thatta, Thana Bulakhan, Hyderabad and Gharo as good sites for wind power generation. Annual values of wind generated electric power computed on hypothetical 600 kW wind turbine come out to be 2.1 million kWh (showing capacity factor of 40%) for Jamshoro, 1.5 million kWh (showing capacity factor of 29%) each for Katibandar and Nooriabad, 1.4 million kWh (showing capacity factor of 27%) for Gharo and 1.3 million kWh (showing capacity factor of 25%) for Hyderabad. Internationally it is accepted that if any site has a capacity factor of 25% and above, then that site is considered to be suitable for the installation of economically viable commercial wind power farms. The above sites and their surrounding areas therefore can be classified as suitable sites for installing wind farms. The identified wind corridor in Sind covers an area of 9700 Sq. kms. Gross wind power potential of this area is 43,000 MW but keeping in view the area utilization constraints, etc., the exploitable electric power generation potential of this area is estimated to be about more than 11,000 MW.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jamshoro	5.0	5.6	6.3	8.3	10.1	12.1	13.9	12.5	9.8	5.9	5.8	6.5
KatiBandar	4.9	5.7	6.2	8.4	9.3	9.3	10.2	8.8	7.2	5.1	4.4	5.0
Nooriabad	4.9	4.8	5.0	7.3	9.3	10.6	10.4	9.7	8.1	4.2	4.4	4.9
Thatta	5.2	4.7	5.4	7.2	8.6	9.1	9.8	9.6	7.3	4.1	4.2	5.1
Gharo	4.6	4.9	5.2	7.4	9.4	9.3	9.1	8.8	7.8	4.4	3.8	4.5
Hyderabad	4.4	4.4	4.3	6.5	8.9	10.0	9.9	8.5	7.8	3.9	3.9	4.8

Fig. 7. Wind speed data of six potential sites of Sind.

4. Microhydel

The water resources of the country are mainly derived from the Himalayan watershed of about 400,000 km^2 with glaciers and snow melt. The major surface water potential is the flow available from the Indus River and its major tributaries. According to Indus Waters Treaty (1960), Pakistan has right for exclusive use of three western rivers (Chenab, Jhelum and Indus). The annual mean discharge (post-Tarbela) of these three western rivers during 1976–2002 at Rim stations (upper most points where rivers enter the plain) is approximately 173 BCM with province-wise distribution as follows [11]:

Punjab: 3.30 BCM; NWFP: 8.94 BCM; Balochistan: 9.62 BCM; Sindh: 0.95 BCM.

Based upon water resource potential, Pakistan's total hydropower potential has been estimated over 40,000 MW, some 24,000 MW of which could be easily harnessed and 6550 MW of which is actually being exploited. Figs. 8 and 9 show hydropower potential in Pakistan and supply demand graph [12]. More than 1000 MW micro/mini hydropower potential is available in northern mountainous region of the country, of which less than 1% is being developed. For microhydel power plants with capacities below 100 kW each and mini hydropower plants with capacities 100–500 kW each, an estimated potential of 300 MW and more than 400 MW respectively exists in this area. The potential areas of Pakistan for micro/mini hydel power generation have been shown in Fig. 10. These include Swat, Shangla, Bunair,

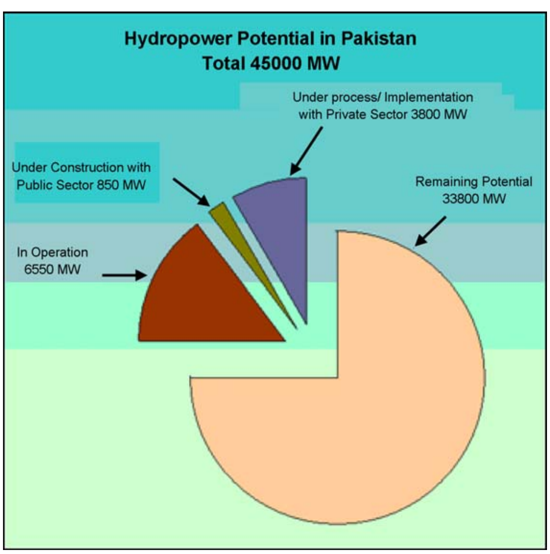


Fig. 8. Total hydro potential of Pakistan.

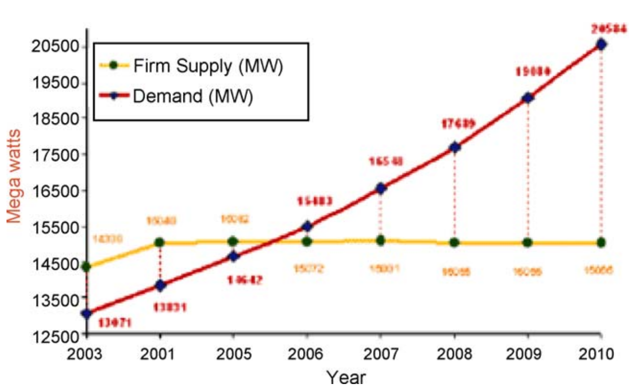


Fig. 9. Electricity supply and demand of the country.

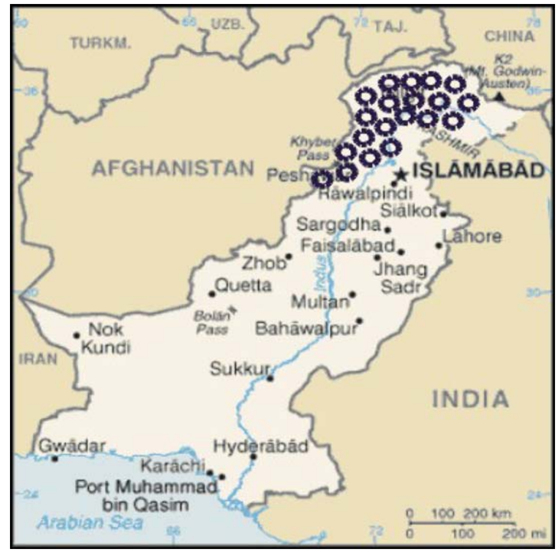


Fig. 10. Potential sites for microhydel power generation.

Gilgit, Chitral, Diamir, Dir, Abbotabad, Mansehra, Azad Kashmir, FATA tribal area, etc.

5. Biogas

Pakistan, being an agricultural country, has a large potential for biomass energy. People living in rural areas are benefiting from biomass energy in various forms such as wood, crop residues and biogas. The precise information about total amounts of wood and crop residues in the country is lacking. So it is difficult to assess the potential of biomass energy in each of its forms. However, it is possible to assess the potential of biogas generated from animal waste using practical experience. There are approximately 57 million of animals (buffalo, cattle) with annual growth rate of 8% in the country [13]. On average, the daily dung dropping of a medium size animal is estimated at 10 kg. This would yield a total of 570 million kg dung per day. Assuming 50% collection, the availability of fresh dung comes to be 285 million kg/day. Based on assumption that 20 kg (wet mass) of dung can produce 1 m^3 gas/day [6] at 25 °C, the total biogas production can be 14.25 million m^3/day. Since 0.2–0.4 m^3 [14] gas could suffice the cooking needs of a person per day, therefore 14.25 million m^3/day of biogas could meet the cooking needs of 36–71 million people depending upon consumption rate. The total population of Pakistan is about 160 million, out of which 70% reside in the rural areas, which comes to be 112 million. Therefore cooking requirements of 32–63% of the rural masses can be met from this source of energy (biogas) alone. Besides this, 25.6 million kg/day of nitrogen-enriched bio-fertilizer can also be achieved to sustain the fertility of agricultural lands. Whereas the biogas data and bio-energy production from animal waste presented by Ghaffar [6] looks to be an exaggerated data. The analysis of biogas being produced by the plants in Pakistan has shown following composition of the gas [15]: Methane (CH_4) 60–70%; Carbon Dioxide (CO_2) 30–35%; Nitrogen (N_2) 1%; Hydrogen (H_2) 0.1–0.5%; Carbon Monoxide (CO) 0.1%; Hydrogen Sulphide (H_2S) Traces. Whereas the composition of natural gas being supplied in the country for domestic and commercial use is as follows [16]: Methane (CH_4) 90.45%; Nitrogen (N_2) 3.32%; Oxygen/Argon 0.05%; Ethane 3.56%; Carbon Dioxide 1.34%; N-Pentane 0.05%; Iso-Pentane 0.07%; N-Butane 0.17%; Iso-Butane 0.16%; Propane 0.80%; C_6^+ 0.04%. It is strongly felt that high technology digesters, generating good quality gas with capability of sustaining internal temperature under adverse environmental conditions should be adopted and installed in the country.

6. Geothermal energy

Geothermal energy is energy generated from heat stored in the earth, or the collection of absorbed heat derived from underground. Geothermal resources range from shallow ground to hot water and rock several kilometers below the Earth's surface, and even further down to the extremely hot molten rock called magma. Wells over 1.5 km deep can be drilled into underground reservoirs to top steam and very hot water that can be brought to the surface for use in a variety of applications. Geothermal steam and hot springs have been used for centuries for bathing and heating but it was not until the 20th century that geothermal power started being used to make electricity. Geothermal energy can find its way to the surface in the form of volcanoes and fumaroles (holes where volcanic gases are released), hot springs and geysers. With reference to Pakistan, hot springs are of most concern in this paper for identification of geothermal resources.

Numerous hot springs with temperature ranging from 30 °C to 170 °C are present in various parts of the country. Mostly these are found in Northern Area, Chagai Area/Balochistan, Karachi, and Hyderabad/Sind. The Northern Area is located in the extreme north of Pakistan and is characterized by very steep topography and U-shaped glaciated valleys. It extends from 34°40′ to 37°04′ north latitudes and 72°30′ to 77°50′ east longitudes. Some important mountain ranges of the area are Kailas, Rakaposhi, Masherbrum and Karakoram. Greater Himalayas mark the southern boundary of the Northern areas. The geotectonic development of the Himalayas and the Karakoram–Hindukush area is closely connected with the geotectonic evolution of the domain between the Eurasian plate in north and the Afro Arabian and the Indo-Pakistan plates in the south in Paleozoic times [17].

In Northern Areas of Pakistan, there is a concentration of thermal springs. However no young volcanism is known in the Northern Areas, so geothermal activity is likely result of collision and underthrusting the Indian Plate beneath the Eurasian Plate. Many hot springs are found along the Main Mantle Thrust (MMT) at Tatta Pani, Sassi, Burmodin, etc. and the Main Karakorum Thrust (MKT) at Murtazabad, Buledas, Chu Tran, etc. Of these, the reservoir temperature of Murtazabad and Budelas is estimated to range from 172 °C to 212 °C. The hot springs are concentrated at Murtazabad including the Hakuchar manifestations. The hot springs at Murtazabad and Budelas are assumed to be of highest temperature reservoir in the Northern Area. This area can be selected as a priority area in Pakistan but $CaCO_3$ scaling however is likely to cause some problem at the development stage. Out of three geothermal manifestations at Budelas, the nearest manifestation to Karakoram Granodiorite has a high potential. The reservoir temperature is estimated to range from 172 °C to 189 °C. Water near boiling temperature (91 °C) is coming out of this hot spring. The geothermal manifestations at Tatta Pani are located on the right bank of the Indus River along the Karakoram highway along a straight line. The springs and seepages are numerous and stretch along a 2–3 km wide zone located approximately 33 km SW of Gilgit town. Rakhiot Bridge is in the vicinity of these springs. The springs emanate from unconsolidated to semi-consolidated fluvial deposits or talus. Amphibolites which are fractured by the Main Mantle Thrust constitute the hard rocks exposed around these geothermal manifestations. The springs are located at an altitude of 1200 m. A brief description of the physical features of four hot springs at Tatta Pani is as follows:

- Temperature: 65.5–83 °C (at ambient temp.: 17–37.4 °C)
- Flow rate: More than 34–800 l/min
- pH: 7–8.83
- Electric conductivity: 1540–1060 μs/cm
- Feature of hot water: Colourless, H_2S smell, salty taste
- Geology: Terrace deposits/Talus/Fractured Amphibolite (Kamila)

A geothermal manifestation is also located in Mashkin on an unmetalled road off the Karakoram highway leading to Astore. The temperature of hot water is 57 °C (at ambient temp. of 34.4 °C). The Sassi thermal spring is located near the Sassi village on the left bank of the Indus River at an altitude of 1460 m whereas the Chu Tran hot spring is located in the Basha valley on the right bank of the Basha River. The temperatures of these two springs are 54 °C and 43.9 °C respectively at ambient temperature of 33 °C. The water is colourless, odourless with pH 7.84/7,74, electric conductivity 1310/5090 μs/cm with $CaCO_3$ deposition. The geology of these two springs pertains to Talus/Gneiss (Kohistan Island Arc Sequence) and Talus/Limestone (Eurasian Mass) respectively. The chemical analysis of water from various thermal springs of Northern Area has shown that total TSM in water ranges from 100 mg/l to 1430 mg/l and can be classified as HCO_3 or SO_4 type. The geothermal systems at Murtazabad and Tatta Pani are shown in Figs. 11–13. As to the heat sources, the obvious evidence such as

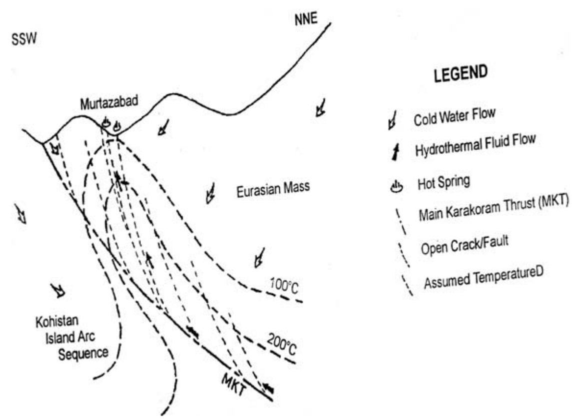


Fig. 11. Profile showing Murtazabad geothermal manifestations in relation to main Karakoram thrust.

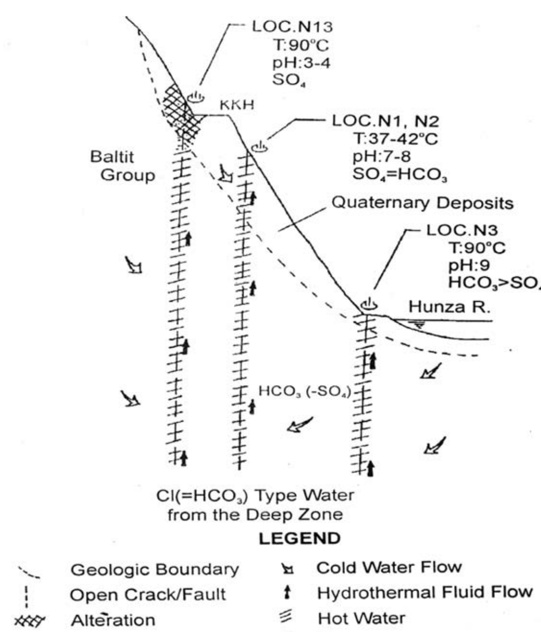


Fig. 12. Profile showing Murtazabad manifestations with probable geothermal system.

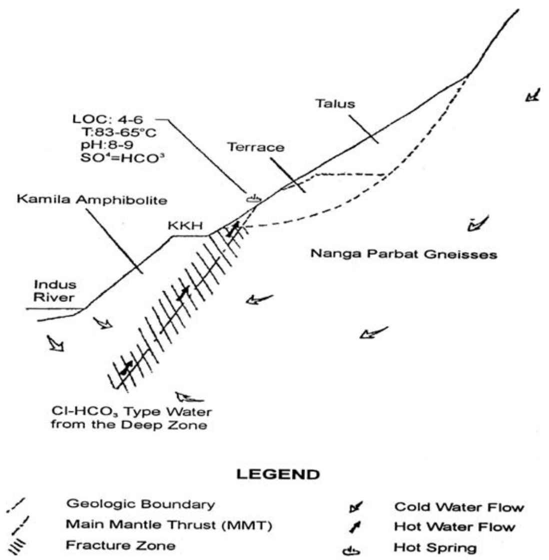


Fig. 13. Profile showing Tatta Pani manifestations with probable geothermal system.

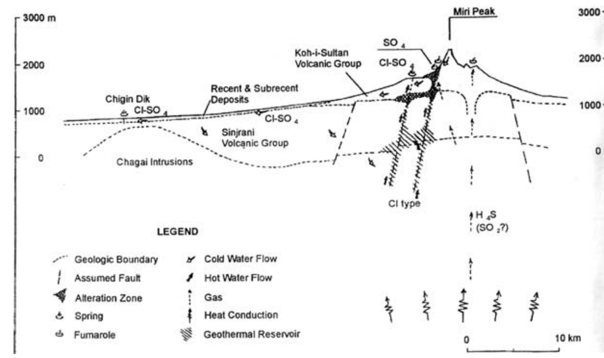


Fig. 14. Conceptional model of Chagai geothermal system.

the existence of a young volcano is not found in the northern areas. However, the heat generated due to friction along the MKT and that due to radioactive decay of the Karakoram Granodiorite is likely source of heat giving rise to the thermal springs while the origin of water can be ascribed to the glaciers.

In the Chagai area, the springs are concentrated in the southern part of Koh-i-Sultan. The Koh-i-Sultan volcanic group is divided age wise into basal agglomerate, top agglomerate, coarse pyroclostic deposit, tuff, lava flow and ash flow. The Koh-i-Sultan volcanic group lies conformably on the Sinjrani volcanic group, the Chagai Intrusions and the Juzzak Formation. The lower slopes of the volcanics are overlain by an apron of subrecent gravels formed by denudation of the volcanic rocks. The volcanic group is likely to be older than Pleistocene. Other than Chagai area, thermal springs of importance are located in the hill ranges north and north east of spintangi railway station in Sibi district. Of these the spring at Talu is well known. The water temperature of hot springs of this area is not high. The spring water which mainly consists of ground water is mixed with hydrogen sulphide gas and is forming the alteration zone. The latest eruption age of the Koh-i-Sultan volcanic group is presumed to be Pleistocene and the eruption was fairly large. It indicates that heat in the magma chamber is adequate and that this area has high heat conductivity. The extinct volcanic still continues to supply sufficient heat and many springs and sulphur deposits are scattered in the acidic alteration zone of Koh-i-Sultan. The existence of geothermal reservoir is expected under the south-western portion of Koh-i-Sultan. According to one research, hydrogen sulphide and sulphur dioxide gases are still emitting from furmaroles. If the emitting of sulphur dioxide is fact, the existence of high temperature magma is inferred. The conceptual model of Chagai geothermal system is shown in Fig. 14. Based on the geological structure, it has been concluded that numerous fractures with high permeability are likely to occur in the Sinjrani volcanic group near faults. As to geothermal fluid, it is uncertain that the fluid exists in the fractures because the annual rainfall in the Chagai area is very low. However water in the hole of Chigin Dik is observed at a depth of 2.4 m. Therefore the groundwater is likely to permeate the deep zone and the Sinjrani volcanic with secondary permeability imparted by faults and fractures are likely to act as the reservoir.

The Chagai area is one of the least developed areas in Pakistan where electricity and water supply do not exist but in this area not only copper, and gold but also tin and tungsten deposits have been discovered at Saindak. Keeping in view its resource potential, Govt. of Pakistan must have to accord priority for electrification of this under-developed area. Seven springs have been reported at different localities in Chagai area. The reservoir temperature calculated by the application of geothermometers is not reflecting true reservoir temperature in all cases. It is assumed that process of mixing of groundwater with gases does not show the reservoir temperature at all. The water of these springs is characterized by very high concentration of salts. The electric conductivity is more than 10,000 μs/cm and the TSM ranges from 13,700 mg/l to 67,540 mg/l, average TSM is 29,476 mg/l. The waters are divided into two groups, SO_4 type and Cl–SO_4 type.

In Karachi, hot springs are located at Mango Pir (west district) and Karsaz (east district). A leper asylum is located near hot spring of Mango Pir and special baths are provided for the lepers. According to a researcher, the curative effect of this water is due to the presence of arsenic in it. The physical features of hot springs at Mango Pir and Karsaz are as follows:

Parameter	Mango Pir	Karsaz
Temperature (°C)	50.3 (at ambient temp.: 36 °C)	39.0 (at ambient temp.: 35.4 °C)
Flow rate	Undetermined	Undermined
pH	7.45	7.87
Electric conductivity (μs/cm)	2380	7910
TSM (mg/l)	1560	5780
Feature of hot water	Colourless, Odorless	Colourless, H_2S smell
Geology	Surface soil, CO_2 gas bubbling	Unknown, CO_2 gas bubbling
Other	Use for bathing	–

The hot spring water at Mango Pir and Karsaz are classified as Cl–HCl_3 and Cl–SO_4 types. The source of the hot water is assumed to be precipitation and have mixed with sea water, especially in the Karsaz hot spring, because this area is located very near the Arabian Sea and the hot spring water contains high Na and Cl. For these two hot springs, the Silica and Na–K–Ca geothermometers indicate reservoir temperature in the range of 71 °C to 98 °C and 138 °C to 170 °C respectively. The Na–K–Ca geothermometer shows high temperature but it appears that the reservoir temperature is not so high because the chemical composition of the hot spring water is subject to the influence of the mixing of sea water and silica content is low. The reservoir temperature (i.e. 71–98 °C) indicated by the Silica geothermometer may be close to the actual reservoir temperature. The conceptual model of Karachi geothermal system is shown in Fig. 15. The Gaj Formation generally consists of shale with subordinate sandstone and limestone whereas Nari Formation consists of standstone, shale and subordinate limestone. The Gaj Formation and Nari Formation

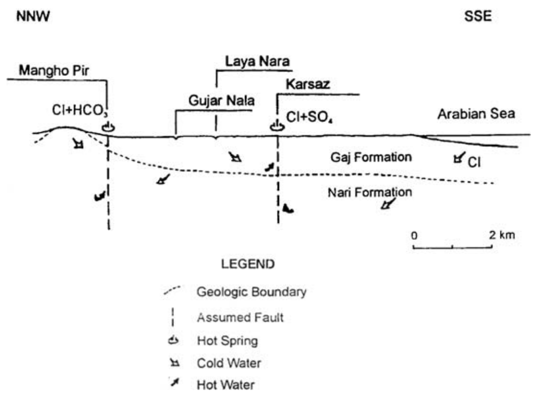


Fig. 15. Conceptional model of Karachi geothermal system.

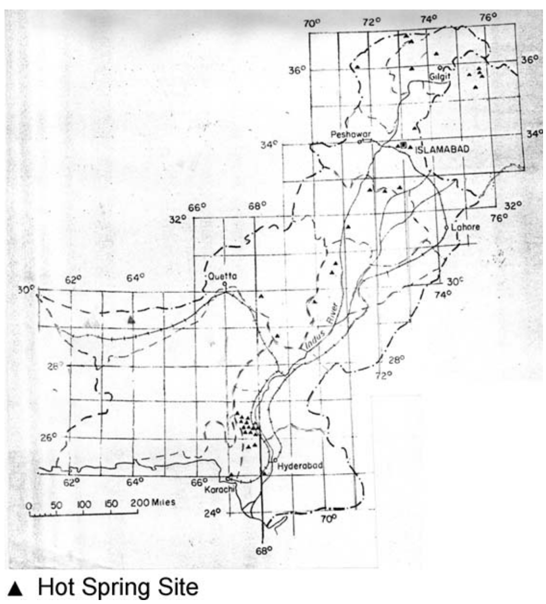


Fig. 16. Hot spring sites of Pakistan.

were introduced by Blandford and Williams in 1976 and 1959 respectively. On the basis of the fossils, the main parts of the two formations are Miocene and Oligocene to Paleocene respectively. Other than the springs in Karachi, the hot springs of Lakhi and towns of Sehwan (Lat 26°23′: Long 67°54′) in Dadu district are known for long time [18].

The hot springs are also found at the following localities of Pakistan [18], mostly in Sind and Northern Area but their therapeutic value is not known:

Jein Pir, Tong, Pekran, Rani-jo-Kot, Khosra-ke-Wahi, Garm-Ab, Khai, Kandhar, Pir Ari, Naing, Phadak, Gorandi, Ghazipir, Tando Rahim Khan, Wahi-Pandi, Uch, Garm Ab (at the foot of the Marri Hill), Zinda Pir, Taunsa, Bakkar, Bukh Ravine, Turnawai, Hoto, Sneuron, Nammal Gorge area/Mianwali, Ratta Hotar/Rawalpindi, Izh Spring/Chitral, Pechus Spring (near Chhatiboi Glacier), Garam Chashma/Lutkho district, Torbutuo Das/Gilgit, Rawat/Darkot Pass/ Yasin Political District, etc. (Fig. 16).

In spite of the presence of numerous hot springs in various parts of the country, no attempt has been made to make use of geothermal energy.

7. Conclusion

The available renewable energy resource data shows that its exploitation priority order should have to be fixed at solar, biogas, microhydel, wind and geothermal energy respectively and Pakistan having huge resource potential must generate at least 10% of its energy demand through renewable energy resources. If available resources would have harnessed through adequate planning and implementation, the country could have surplus energy to supply instead of being fixed in present energy crisis.

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